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UNITED STATES OF AMERICA:
WAR DEPARTMENT.

SIGNAL SERVICE NOTES NO. XX.

THUNDER-STORMS OF MAY, 1884.

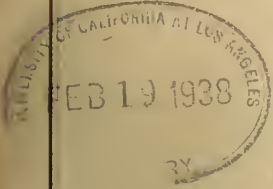
PREPARED UNDER THE DIRECTION OF
BRIG. & BVT. MAJ. GEN'L W. B. HAZEN,
CHIEF SIGNAL OFFICER OF THE ARMY,

BY
H. A. HAZEN,
JUNIOR PROFESSOR, OFFICE OF THE CHIEF SIGNAL OFFICER.

BY AUTHORITY OF THE SECRETARY OF WAR.

WASHINGTON CITY:
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NOTE.

The publication of this Signal Service Note is made for the purpose of bringing it to the attention of the public. The Chief Signal Officer does not thereby necessarily endorse the views set forth.

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THUNDER-STORMS OF MAY, 1884.

The subject of thunder-storms has attracted much attention of late and a special effort has been made in many foreign countries to collect detailed observations of them. By such observations it is hoped to elucidate the causes underlying their formation, their method of development and their general history. In this country general observations have been made by volunteers under instructions from the Smithsonian Institute as far back as 1849, and by the same with those of the Signal Service since 1871.

These observers have necessarily been far apart and not as uniformly distributed as would be needed for a systematic study of the phenomenon. In January, 1884, the Chief Signal Officer entered into correspondence with the Post Office Department looking to a more uniform distribution of thunder-storm observers through the co-operation of that department.

On March 1, the following card for the detailed observation of such storms, with the accompanying circular (No. 4) of instruction was issued:

[Form 169.]		THUNDER-STORMS.	
Data collected by co-operation of Post Office and War Departments.			
Town.....		County.....	
State.....		Kind of time used.....	
Date (month and day).....			
Thunder....	{	First heard.....	
		Last heard.....	
Direction....	{	Coming from.....	
		Going towards.....	
		Began.....	
Rain.....	{	Ended.....	
		Amount.....	
Hail.....	{	Began.....	
		Ended.....	
		Amount.....	
Wind.....	{	Before..	{ Dir.....
			{ Force.....
	{	After..	{ Dir.....
			{ Force.....
Distant Lightning.....			
.....			
.....			
.....			
.....			
Remarks.....			
.....			
.....			
.....			
.....			
Observer.			

[CIRCULAR No. 4.]

SIGNAL OFFICE,

WAR DEPARTMENT,

Washington, March 1, 1884.

It is desired that during the summer of 1884 a few simple facts be collected relating to the important subject of thunder-storms. To this end post-offices and other centres have been selected, over a limited extent of country, at distances of about forty miles. Each station, it will be readily seen, forms an important point in the network of stations, and by a comparison of these observations it is hoped that valuable acquisitions may be made to our knowledge of these frequent accompaniments of tornadoes. Each thunder-storm should have some note made of it, in order that there may be no gap in any region.

The following instructions are given for guidance in making observations. Each card will have sufficient space for three storms. Give town, county, state, time (whether "mountain," "central," "eastern," or some city), and name of observer.

Thunder-storms twelve hours apart may be taken as separate storms.

Upon the occurrence of thunder give in the appropriate spaces month and day, and, as near as possible, the time of first and last thunder connected with the storm. Frequently after a storm has passed there will be muttering of thunder, but care should be taken to, as far as may be, watch the single storm.

Give the direction from which the storm appears to be coming, as shown by threatening sky, lightning flashes or thunder peals. Also, the direction towards which it goes.

Give time of beginning and ending of rain, with amount, if possible.

If the rain continues rather heavy more than two hours after the loudest thunder has passed, it may be marked "more than two hours."

The amount of rain can be measured, with a common rule, after it has been caught in a pail or empty tomato can with vertical sides.

All observations of hail, size of stones, &c., are very important.

Give directions and force of wind before and after the thunder-storm; for the force adopt the scale of calm, light, moderate, brisk, high, very high, hurricane or tornado.

If you have a thermometer give the shade temperature, or temperature on north side of house, a little before the storm reaches the station as well as after it has passed.

Note, also, if on any day heat-lightning is seen, the date, time of appearance, and direction.

If there is not time for a full report, give date and time of severest part of thunder-storm. Please do not fail to make some note of every distinct thunder-storm that passes over, or within ear-shot of, the station.

Observations should begin immediately upon the receipt of the cards.

This circular is issued with the sanction of the Postmaster General.

If you know some one in your immediate neighborhood who takes an interest in meteorology and would be willing to report, you are at liberty to hand these cards to him.

W. B. HAZEN,

Brig. & Bvt. Maj. Gen'l,

Chief Signal Officer, U. S. A.

These were sent to post offices forty miles apart, from the Atlantic to the 102th meridian west of Greenwich, and from the 35th parallel of latitude to the northern boundary. In Indiana, Illinois, and the circle of one hundred and fifty miles radius, with Washington as its centre, stations have been selected ten miles apart. These cards met with favorable response in a majority of cases, and all records of

hail-storms in May and for thunder-storms on May 18 and 19 have been selected for a special study. Reports of five hundred different storms have been received. From these the following facts have been gleaned. Table I. exhibits a list of all the hail-storms that have been noted.

TABLE I.—*Hail-storms and their relation to "LOW."*

Number.	1884.	Station.	Low.		Pressure.	Size, &c., of hail-stones.
			Direction from.	Distance to.		
	<i>Date and hour.</i>			<i>Miles.</i>	<i>Inches.</i>	
1	April 23, 8 p. m.	Concordia, Mo.	se.	210	29.4	Pigeon's eggs.
2	29, 5 p. m.	Montevideo, Minn.	e.	200	29.6	Slight.
3	May 3, 7.10 p. m.	Franklin, Ind.	ne.	900	30.1	
4	4, 2 p. m.	Rockport, Dak.	e.	100	29.6	Small.
5	5, 3.30 p. m.	Troy, Mo.	s.	100	29.6	Large as hen's eggs.
6	6, 8 p. m.	Dayton, Ohio.	e.	50	29.8	8-14 inches deep.
7	8, 8 p. m.	Rothrockville, Pa.	se.	125	29.9	Heavy.
8	9, 1.10 p. m.	Ludlow, Pa.	s.	120	29.8	Small.
9	10, 7.15 p. m.	Mooreville, Ind.	se.	240	29.8	Large as peas.
10	11, 9.55 a. m.	Lyons, N. Y.	sw.	40	29.6	Large as buckshot.
11	11, 2 p. m.	Statesville, N. C.	*	*	29.75	.3" deep.
12	11, 3.15 p. m.	Cowpena, S. C.	*	*	29.75	Large as partridge eggs.
13	12, 6 p. m.	Ft. Madison, Iowa.		0	29.75	3" circumference.
14	16, 1.10 p. m.	Ogallah, Kans.	e.	100	29.8	
15	17, 5 p. m.	Fall River, Mass.	s.	125	29.7	Good size.
16	17, 5 p. m.	Providence, R. I.	s.	125	29.7	
17	18, 4 a. m.	Murphysboro, Ill.	s.	300	29.7	Small.
18	18, 2.30 p. m.	Waverly, Ill.	s.	300	29.7	
19	18, 7.30 p. m.	Worthington, Ind.	se.	270	29.7	
20	19, 12.20 p. m.	Vevay, Ind.	s.	300	29.6	Size of buckshot.
21	19, 12.20 p. m.	Westerville, Ohio.	se.	300	29.5	.5" in diameter.
22	19, 2.10 p. m.	Cheshire, Ohio.	se.	350	29.6	
23	19, 6.30 p. m.	Statesville, N. C.	s.	000	29.8	
24	19, 7.15 p. m.	Marion, Va.	s.	580	29.8	.5" in diameter.
25	19, 8.30 p. m.	Sandy Spring, Md.	se.	500	29.8	
26	20, 8.45 p. m.	Sherlock, Kans.	e.	50	29.6	Light
27	21, 12.05 a. m.	Cleburne, Tex.	se.	500	29.9	
28	21, 3.30 p. m.	Allison, Kans.	e.	100	29.0	
29	21, 8.15 p. m.	Maple Grove, Va.	s.	300	29.9	Broke windows, &c.
30	22, 2.05 p. m.	Humboldt, Iowa.	s.	50	29.7	
31	22, 4 p. m.	Sussex, Wis.	se.	150	29.7	
32	22, 4 p. m.	Northfield, Minn.		0	29.7	
33	25, 1 p. m.	Brevard, N. C.	e.	†	30.0	
34	26, noon.	Noblesville, Ind.	e.	*	30.0	Slight.
35	26, 10.20 a. m.	Rising Sun, Ind.	e.	*	30.0	
36	26, 2.40 p. m.	Frankfort, Ind.	e.	*	30.0	Considerable.
37	26, 2.40 p. m.	Stockwell, Ind.	e.	*	30.0	
38	27, 2 p. m.	Fort Wayne, Ind.	e.	*	30.0	
39	27, 7.10 p. m.	Chambersburg, Pa.	ne.	*	30.0	Size of peas.
40	27, 7.40 p. m.	Wytheville, Va.	s.	*	30.0	
41	29, 4 p. m.	Sherlock, Kans.	ne.	300	29.9	
Mean, omitting indefinite			se.	238	29.72	
Mean of all					29.78	

* Not well marked.

† Atlantic.

Ten of the falls occurred when no well-defined LOW was present; the remaining thirty-one occurred in a direction southeast from LOW and at a mean distance of about two hundred and forty miles, with a mean pressure of 29.72 inches. These facts show the prevalence of hail-falls near LOW, and ordinarily with a pressure considerably below the mean.

THUNDER-STORMS OF MAY 18TH AND 19TH.

It was found that the 16th ushered in a system of thunder-storms of great extent and intensity, culminating on the 18th and 19th. Charts A and B have been prepared showing in full black lines the progress of the thunder-storm action for each four hours, beginning with 4 a. m. of the 18th and with 8 a. m. of the 19th. There

is also shown upon each map, by a dotted line, the position and track of the LOW accompanying the storms. The figures 18-1, 18-2, 18-3, &c., on this dotted line show the position of LOW at 7 a. m., 3 p. m., and 11 p. m., respectively.

This LOW was central in Colorado on the 16th, and advanced in an east-northeast direction at a rate of 15.3 miles per hour, or much less than the average May velocity, which has been 25.7 miles per hour for the eight years 1876-1883. Table II. shows the average velocity of LOW for intervals of eight hours on the 18th and 19th:

TABLE II.

Interval.	Velocity.
18-1 to 18-2	32
18-2 to 18-3	21
18-3 to 19-1	18
19-1 to 19-2	27
19-2 to 19-3	7
19-3 to 20-1	21
Mean	21.0

The first thunder-storms accompanying this LOW are reported from Kansas morning and afternoon of the 16th. No storms of importance are reported on the 17th. On the 18th they were general in Illinois and Indiana. On the 19th the region of general action had advanced markedly to the east. Beginning with storms in Indiana in the morning, we find them spreading out like a fan from this region to the southeast and east (see chart B). The extreme eastern limit of these storms of the 19th was Mountainville, New York, where there was no thunder but distant lightning was seen in the southwest. The gradual advance of the storms from west to east and southeast is plainly indicated on maps A and B, by following the lines of general action at each four hours. The average distance apart of these lines on chart B gives in Table III. the velocity of the thunder-storm action during each four hour interval.

TABLE III.

Interval.	Velocity.
8 h. to noon.	52
Noon to 16 h.	49
16 h. to 20 h.	33
20 h. to midnight.	29
Mean	41

This great velocity of thunder-storms above that of the accompanying LOW, amounting in this case to more than double on the 19th, is very interesting and demands further investigation. Are thunder-storms in a measure entirely outside of the influence governing low, or are they at such a great distance from the LOW as to attain a greater velocity going upon a large circumference rather than upon a straight line? The rapid dying out of this action in the later hours of the day, and its starting up again the next morning are also noticeable features.

On comparing the distances of these storms we find the average to be about four hundred and fifty miles from LOW, and the direction southeast.

CONCLUSIONS.

1st. Hail-falls occur ordinarily with pressure much below the normal to the south-east of LOW, and at a distance from it of two hundred to three hundred miles.

2d. Thunder-storms advance from the west toward the east and southeast, generally accompanying a LOW, and in the southeast quadrant at a distance of four hundred to five hundred miles.

3d. The action seems to die down at night and begin again in the morning, and often spreads in a fan shape to southeast and east.

4th. The velocity of the thunder-storms is greater than that of the accompanying LOW.

These preliminary deductions are here made simply as showing, what may be hoped for from a critical examination of reports at stations near each other.

H. A. HAZEN,

Junior Professor,

Office of the Chief Signal Officer.

June 6, 1884.

NOTES.

The following notes are added here in partial extension and explanation of the circular on page 4:

The necessity of placing the town or post office address upon each card will be very apparent, many cards had been received which have lost much of their value because of this omission. It is desired that the post office address be first entered and next the town, if the two do not coincide, *e. g.*, Albany (Menand Station).

The subject of the kind of time used has caused some confusion. In November, 1883, most of the railroads adopted a system of reckoning time which is very convenient and does away with most of the seventy or more previous standards. Four standards are used, which may be designated as Eastern, Central, Mountain, and Pacific. The central meridian for each of these is, for the 1st, 75° ; 2d, 90° ; 3d, 105° , and 4th, 120° , all west of Greenwich. Eastern time is used by railroads and most towns lying between longitudes $67\frac{1}{2}^{\circ}$ and $82\frac{1}{2}^{\circ}$; Central time is used between $82\frac{1}{2}^{\circ}$ and $97\frac{1}{2}^{\circ}$, &c. The simplest method of getting time would be from the nearest railroad, and in such case the only record needed, for "kind of time used," is the name of the railroad furnishing it. If, however, it is found impossible to obtain railroad time, then the kind of time used should be noted thus: "Columbus, Ohio, time," "sundial time," &c.

It is important that in all cases the morning and afternoon records be clearly distinguished. The most convenient method of doing this, and one already adopted by many observers, is to divide the day into twenty-four hours, beginning with 0 hour, or midnight of the previous day, and counting to midnight. By this method 7.15 would indicate a morning observation at 7 o'clock and 15 minutes; 23.15 a night observation at 11 o'clock and 15 minutes. The morning hours would be written as at present, but the afternoon hours would have twelve added to each. If this system is not used care should be taken to place the needed a. m. or p. m. after the figure denoting the time.

In addition to the record called for on the card, it is desired, if possible, to introduce a scale for thunder-storm action, in order to make future comparisons more satisfactory. The following scale is suggested:

1. Distant lightning.
2. Distant thunder.
3. Moderate thunder-storm.

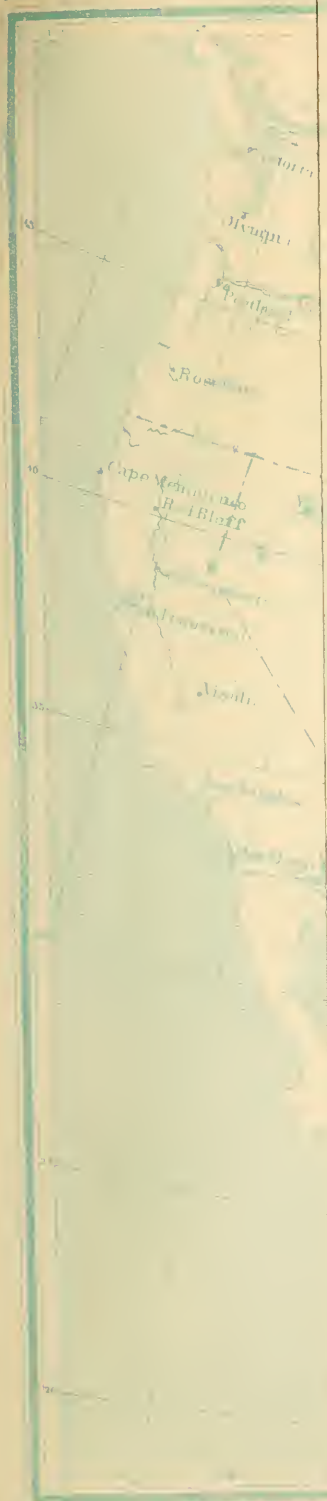
4. Heavy thunder-storm.

5. Heavy thunder-storm, with very high wind, uprooting trees, blowing down buildings, &c.

It is desired that each card be mailed as soon as filled. When there are only two cards left, make note to that effect on the card sent in.

It is not necessary that an observer remain in any one place for all his records, but every thunder-storm should be recorded wherever experienced. Observers are desired in towns where there are none now. Necessary instructions and postal cards will be sent any person who applies to the Chief Signal Officer of the Army.





Full curves show lines of general adsth, 7 a. m.); 18-2 (18th, 3 p. m.); 18-3 (18th, 3 p. m.), &c.

Chart A—Thunder-Storms May 18, 1884.



Full curves show time of general action at 4 a. m., 8 a. m., 12 (noon), 16 (2 p. m.), &c.

Arrows show the storm movement.

Dotted curve shows the path of the low centre. 16-1 (191b, 7 a. m.), 19-2 (184b, 3 p. m.), 16-3 (185b, 3 p. m.), &c.



Full curves show lines of general activity, 7 a. m.); 18-2 (18th, 3 p. m.); 18-3 (18th, 3 p. m.), &c

Chart B—Thunder-Storms May 19, 1884.



Full lines show lines of general action at 4 a. m., 5 a. m., 12 (noon), 12 (3 p. m.), 4 p.

Arrows fly with the storm movement.

Dotted curve shows the path of the low centre. 16-1 (15th, 7 a. m.) 16-2 (15th, 7 p. m.) 16-3 (16th, 2 p. m.), 4 p.

